Art. I.—*Investigations into the Occurrence of Onchocerciasis in Cattle and Associated Animals in Countries other than Australia.*

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(With Plates I.-V.).

[Read 11th March, 1915].

During the tour upon the occasion of which these investigations were made, I was able to visit Java, the Straits Settlements, and Malay Federated States, Ceylon, India, Egypt, Europe, Great Britain, United States of America, Canada and the Hawaiian Islands. In addition, enquiries have been made from responsible officials regarding the other islands of Netherlands India, Burma, Siam, Annam, Southern China, and the Philippines, but very little information has been available in the latter cases. I wish to thank very sincerely those officials in so many places who have given me any assistance in their power, in many instances taking considerable trouble to do the necessary work.

In only two or three cases had we any previous knowledge of these "worm-nodules"; thus, one instance had been recorded (under the name of *Spiroptera reticulata*) of their occurrence near the shoulder of an Indian bullock in Malay (Daniels, 1904) (Gilruth and Sweet, 1912), while they had been found in cattle in Java by J. De Does (1904), and others (Railliet et Henry, 1910). As may be seen in detail in previous papers on onchocerciasis in Australian cattle, there is considerable historical evidence pointing to the importation of the parasitic worm causing these muscle-embedded nodules into Australia from Southern or South-Eastern Asia. It may have been brought in either in 1826-8 in buffaloes from Timor (Cleland and Johnston, 1910 (d)), or in 1824 or 1840 in cattle from Coepang in Timor (Gilruth and Sweet, 1911, p. 34), this latter seeming the more probable, inasmuch as the buffaloes found in considerable numbers in the Northern Territory, which are the descendants of buffalo imported in 1824 and 1826 from Timor and 1886 from India, are not known to harbour this parasite, although careful search was made for it, and for evidence

from hunters and hide exporters, of its existence, while "all the cattle depastured on the same country are more or less affected" (Gilruth and Sweet, 1912, p. 23). On the other hand it was quite possible that it may have been introduced in Indian cattle about April, 1843 (Gilruth and Sweet, 1912, p. 24), inasmuch as the cross-bred descendants of the "Brahma" or Indian cattle in the Territory are more less infected.

As there were, however, no records as to its existence in India, it appeared a matter of some interest to find out somewhat more definitely the actual distribution of this parasite, and to determine the extent of its occurrence elsewhere, especially in countries more or less adjacent to Australia; likewise to collect any information which might throw light on the life-history.

Wherever possible I visited the Chief Veterinary Officer, both Government and Municipal, in each district entered, the Principal Medical Officer, where such was associated with the inspection of meat, Veterinary Schools where such existed, and often also the abattoirs, interviewing the Superintendent and his senior subordinates, and in many cases myself superintending the searching of carcases. Where I was unable myself to visit the district, a letter accompanied by a brief description of the condition under investigation, and a carefully drawn-up series of headings under which information was sought, was sent to the similar responsible officers, with a request that answers should be sent to me by a certain date. In several cases the officials of the various Governments concerned very courteously sent out these papers to their staffs, so giving the enquiry the aid of their authority and influence. Throughout much of the East the difficulties of such an investigation, owing to various conditions which are indicated later, are considerably greater than in countries where European customs and ideas prevail, so that the response has been somewhat disappointing in its extent, though much material and information promised have still to come to hand, so that I hope to be able to report further later on.

PART I.—GEOGRAPHICAL.

Before passing on, it is necessary, in order to avoid confusion, to indicate the types of bovines considered in the following pages:—

(1) *Bos taurus:* This term is used as including the well-known common tame ox of Europe and Northern Asia, and not in the restricted sense of Lydekker (1913, p. 12).

(2) *Bos indicus:* This term is used as indicating not necessarily a zoological species, but the common domesticated humped cattle of India, etc., often known to naturalists as the Zebu. This name does not appear in Lydekker's catalogue of Ungulate Mammals, a most remarkable omission in view of the fact that he quotes the names of other domesticated races of bovines in this which purports to be a complete catalogue of Ungulates. The humped Indian cattle are also called Brahman and sacred cattle, and are of several types of varying size and build, and useful in various ways, all having a very large sharply outlined hump on the withers, long ears, and a large loose dewlap and very full throttle. (See Fig. 1.) As to the origin of this form, we are not in a measure concerned, yet the question has the possibility of considerable interest in regard to the original host and place of origin of *Onchocerca gibsoni* and its allies. Two views have been held—one that of Blyth, that Africa was the original home of the ancestors of *Bos indicus;* the other, first suggested by Rutimeyer in 1878 and upheld by Lydekker, and the theory to which evidence strongly points as being correct, that the ancestor of the Zebu is to be found in the Indo-Malay group of cattle, which includes the Indian gaur (*Bos* (*Bibos*) *gaurus*), of which the Seladang of the Malay Peninsula is a variety (*Bos gaurus hubbacki*), and the Javan Bantin (*Bos* (*Bibos*) *banteng—Bos sondaicus*). As Lydekker states (1912, p. 153), since Rutimeyer's work, "the range of the Bantin (*Bos sondaicus*) has been found to extend into upper Burma, . . . and an examination of a large series of skulls and heads leads me to conclude that Rutimeyer was probably right in regarding this species—or possibly a nearly allied extinct type—as the ancestor of the Zebu." There are undoubtedly many hybrids of these two domesticated forms at least in Java, where also a certain admixture is stated to have taken place with the Bantin, and many of them are almost indistinguishable from the purer domestic breeds, so that at times possibly hybrids are included under one or other of the terms *Bos taurus*, and especially, *Bos indicus*.

(3) *Bos* (*bubalus*) *bubalis:* This is the recognised specific name of the Indian buffalo, water buffalo, Kerabau (in its various forms, e.g., Karibouw), or Arni, see Figure 2. This has thick, short limbs, and a massive neck, a dewlap being absent, its thick black skin carrying sparsely scattered, long, coarse black hair. The head, with its semicircularly curved horns, is carried well forward and low, so that the horns are more or less in the same plane with the neck. Rarely, a pinkish-skinned animal, with white hairs, may

be seen. As their name indicates, they are invariably to be found, when not working or feeding, wallowing in water-pools and covering themselves with mud.

The Malay Archipelago.

As already mentioned, the presence of "worm nodules" in the muscles of cattle in Java had already been noted and recorded by De Does and others, who have regarded them as being *Onchocerca gibsoni*.

While in Java, I had opportunities of conference with a number of Veterinary Surgeons, some of whom were able to throw a certain amount of light on the question, and, further, the authorities of the Government Veterinary School at Buitenzorg were good enough to undertake to make enquiries throughout the Dutch possessions in this archipelago in order to determine the range, hosts, and general conditions governing the occurrence of these nodules; so that it is hoped further information on these points may be forthcoming later.[1]

The nodules were first discovered by Mr. Hellemans in cattle in 1901 at Kediri (S.W. of Soerabaja), when a thorough meat inspection first began there, and have been constantly found there since, and in other parts of the valley of the River Brantas, such as Toelengagoeng, Blitar, and Pare, and at Rembang, Sloeke, and Madioen. Statistics given of their occurrence vary from 40 per cent. by earlier observers to 80 or even 90 per cent. of carcases later, an increase possibly due to greater familiarity with their existence and appearance. They are almost invariably found near the mid-line of the sternum, sometimes in considerable numbers, e.g., from 20 to occasionally 40 per carcase, and Hellemans reports having seen them rarely, in the stifle. Since the cattle are never killed until too old or weak to work, the nodules are unknown by post mortem examination except in 6, 7, or even up to 10 year-old animals, the worms being generally dead, and most of them caseous or much calcified, though it is stated by one observer that one may find a "very small *young* nodule beside the calcified ones."

De Does reported to me having seen filarial larvae in blood-smears of infected animals, but admits that they may have been those of some filarial worm other than *Onchocerca gibsoni*, such as aortic filariae, etc. He has also seen larvae "not only in the tunnels

1 See Addendum 2.

around the worm and in the connective tissue, but also *in a vein* in the wall of the same nodule. In this case, the larvae were quite probably those of *O. gibsoni*, but may have been carried by the knife into the vein space, in sections of a whole nodule, so that one cannot accept either statement as proof of the occurrence of the larvae of this worm in the bloodstream.

Hellemans was also able to find these nodules in Sumatra, when the more thorough meat inspection was instituted at Padang in 1904—but, strangely enough, after his experience of finding them in Java in the brisket almost entirely, here in Sumatra he was unable to find them in that location, detecting them in 25 per cent. of cows, and then in the stifle only.

Regarding *Bali*, nodules have also been seen in the brisket, and rarely on the flanks of cattle imported into Batavia from Bali, but no work has been done on the island itself.

In cattle imported into Soerabaja from Madura, nodules are so far unknown.

Nothing whatever is known of Lombok or Timor in this connection, and the infrequent communication rendered any attempt on my part to visit these islands impossible.

The term "cattle" used above undoubtedly includes *Bos taurus* from Europe, and Australia, and locally bred; and probably also pure-bred and hybrid *Bos indicus*. This term has been used here because of the difficulty of determining the absence of admixture even in so-called pure-bred cattle of either species; and it must be remembered that there is still some question as to the amount of interbreeding which may have taken place between those two domesticated races in Java, as authorities there are very conflicting on the point.

It was naturally a point of some interest to discover whether the nodules were present in the pure bred descendants to the humped cattle or Zebus (*Bos indicus*), which had been imported from India (Bengal), and also in any known hybrids with the ordinary cattle, (*Bos taurus*). I was informed that these nodules had not so far been seen in these pure-bred *Bos indicus*, nor in any of their hybrids, except as was stated by De Does, that he had seen them "in such hybrids in parts of West Java (where there are very few cattle), along the midline of the sternum, especially in animals of 2-3 years."[1]

Naturally also, the Bantin or native ox of Java (*Bos banteng*) forms a possible host for these worm-nodules, but I was unable to

1 But see Addendum 2.

obtain any evidence of their occurrence in this animal in either Java or Sumatra.

In the Karibouw, or water buffalo (*Bos bubalis*), worm-nests are well known to both Dr. Sohns and Mr. Hellemans. They occur at Kediri in Java, and also in Sumatra, always in the skin of the animal. Unfortunately I have not as yet been able to obtain any specimens suitable to determine whether the worm-nodules found in this constant position in the buffalo, belong to the same or a different species from *O. gibsoni*. Macroscopically no difference whatever has been seen in specimens from the two positions in *Bos taurus* and *Bos bubalis* in Java.

Inquiries were made with regard to the general conditions of those places from which the infected cattle come, and as to the animals found there which might possibly act as intermediate hosts, if such be necessary for the completion of the life history. In Java, Sumatra, and Bali all areas carrying infested cattle are similar in being low-lying and swampy, or flat, with much stationary water, and, as might be expected under those conditions, mosquitoes are very numerous. Biting flies do not seem to be especially frequent.

Although not immediately concerned with the object of the present investigation into forms found in the connective tissues, it is of interest to remember the existence of two kinds of filarial worms in the aortic walls of bovines in these regions, viz., *Onchocerca armillata*, Raill. et Henry, 1909, and *Elaeophora* (=*Filaria*) *poeli* (B. Vryburg, 1897). The former, which lies sinuously beneath the lining epithelium of the aorta of cattle (*Bos indicus*), has been recorded by Railliet and Henry (1903, and 1912, p. 117), from Sumatra (*vide infra* also). The latter, *E. poeli*, forms tumours in the walls of the aortae, containing the head of the female worm and one or more males, the remainder of the female worm floating about in the direction of the bloodflow. It has been recorded already by B. Vryburg (1897), and by Railliet and Henry (1912, p. 115), from the aorta of the Buffalo (*Bos bubalis*), and rarely of cattle (*Bos indicus*) from Sumatra, and it was quoted to me also from Java.

Pacific Islands.

As time did not permit me to visit the Philippine Islands, enquiries were made from the Bureau of Science at Manila, in reply to which the Director of the Bureau reported that "Onchocerciasis is not endemic in the Philippine Islands. It has been found in cattle shipped from Australia for slaughter in the Philippines, but no case has been reported in native cattle or carabaos."

Similar conditions appear to exist in the Hawaiian Islands which were visited.

Malay Peninsula.

As already known, worm-nodules were found by Mr. T. A. Ford in Malaya in 1904, and recorded under the name of *Spiroptera reticulata* by Dr. Daniels (1904, p. 17). These came from an aged specimen of *Bos indicus*. I visited a number of official Veterinary Surgeons in the Peninsula, and enquiries were made from others, but none so far seem to have been able to detect them elsewhere, though while this report was nearing completion, I received from Mr. Ford specimens from an old working Indian bullock, and from 17 small Siam bulls (from the west coast of Siam, about midway between Penang and Rangoon), the latter having been brought to Kuala Lumpur for slaughter. The nodules vary in number from 1-20. The fact that cattle are never killed unless incapable of work, naturally diminished the likelihood of the nodules being found, but it does not seem credible that they are so restricted in distribution in the Peninsula, especially in view of experiences elsewhere. Thus, at Penang inquiries were made, and finding that their existence had not been noted, I accompanied the Municipal Veterinary surgeon to the Abattoirs, where I interviewed his Chief Inspector, and made with them an examination of the carcases then in the houses. That they were well known to the Inspector, although he had not previously reported them, was quickly seen, as without any advice from myself he immediately cut in two inches to the side of the midline of the sternum of an Indian bullock, disclosing three nodules exactly similar to *O. gibsoni* in appearance and position. These were found to be mature, and contained living and actively motile larvae. The nodules were present to the number of 1-3 in nearly all the cattle killed that day, but none could be found in any of the buffalo then in. I was assured, however, by the Inspector, evidently a careful observer, that they are quite frequently found in Indian cattle (*Bos indicus*), and in more than 20 per cent. of the "native" brown Malay cattle, and in the small humped Siamese cattle, both of which appear to be varieties of *Bos indicus*—always in the brisket, but usually only up to three per animal, varying up to the size of a walnut. They are also found but comparatively rarely in the "native" buffalo or Karibouw (*Bos bubalis*). In the face of this evidence it seems credible that a more careful search will reveal the presence of these worm-nodules widely spread in the cattle and buffalo on the mainland.

It would have been of interest to find whether these nodules are present or not in the Seladang, or wild Malay gaur (*Bos gaurus hubbacki*), but, unfortunately, no evidence whatever was forthcoming.

The two bovine aortic worms previously referred to are also present, as I was able to see in Malaya and the regions to the North, as has been recorded already, though not always by name, by various authors, and first of all by Ford (1902); thus, *O. armillata* has also been recorded in bullocks, and rarely in buffaloes (less than 1 per cent.) by Tuck (1904, p. 30), from animals killed at the slaughter-house at Kuala Lumpur (F.M.S.). They are also described from cattle killed at Hué (Annam) by Bernard and Bauche (1912, p. 112) and Railliet and Henry (1912, p. 117), while *E. poeli* (under various names) has also been recorded by Von Linstow as *Filaria haemophila* (1904, p. 352), from buffalo, by Tuck (1904, p. 20), from buffalo and bullock (?) (p. 32) at Kuala Lumpur, by Ford (1907, p. 517) from buffalo (in 72 per cent. of carcases examined) at the abattoirs at Kuala Lumpur, and also in buffaloes in the country districts of Selangor, Negri Sembilan, and Pahang, by Bernard and Bauche (1912, p. 109) (83 per cent. of buffaloes and 1 per cent. of oxen being affected), and by Railliet and Henry (1903, p. 254; 1912, p. 115) from Hué (Annam).

India and Ceylon.

Hitherto worm-nodules in the connective tissues have never been recorded from India or Ceylon, and, except in one instance, have been quite unknown there. Leiper states that Lingard has recorded Onchocerciasis in India—this refers, however, only to Aortic worms. The difficulties of the investigation are considerably greater than elsewhere for several reasons. The number of cattle killed is proportionately small, and they are even then, as in Java and Malay, almost invariably aged (e.g., 7-10 years is the usual age in many parts), and are only killed because they are no longer able to work. Also, the amount of meat consumed is proportionately less than in colder countries; and, further, in many places, it is almost entirely one section of the native population alone which uses the flesh of the local animals for food, the meat supply for the European residents being largely imported frozen. As a result of this, detailed meat inspection, even as we know it, is unknown, more especially in most parts of India. Although a form of meat inspection exists as elsewhere, the ordinary process was absolutely useless for my

purpose, being conducted at the best chiefly by native veterinary officers watching for specific diseases, under the general supervision of a fully qualified European Veterinary officer who, however, has not only a very extensive area to control in this respect, but has also charge of all matters affecting the health of the animal population of the district, and has often to combat outbreaks of disease under considerable difficulties. In the ordinary abattoirs the animals are often killed between midnight and 1 a.m., and are taken away almost immediately for consumption, after cursory examination for certain diseases, so that the parts of the carcass concerned in this question are very rarely examined. This, added to the method of killing used, made any personal investigation neither easy nor pleasant. A somewhat similar condition as regards detailed inspection is normally found in the special abattoirs attached to meat drying Factories, which supply the trade to Burma more especially. In these, however, in some places more buffalo than bullocks are killed, and from these evidence was obtained, though no nodules could be found in the carcasses present at the time of my visit in one of these which I was able to visit personally.

The religious importance of the cow to the Hindu, to whom this animal is most sacred, gives rise to further difficulties in the way of such investigations—even in Serum Institutes and Research Laboratories, the animals appear to be less frequently killed than in many similar institutions elsewhere, while at the various Veterinary Schools and Hospitals, even if their native Hindu owners allow the animals to remain there to die, permission to make post-mortem examinations can very rarely be obtained. However, through the courtesy of the Department of Revenue and Agriculture of the Government of India, official circulars were sent to all Local Governments and Administrations, requesting that the resources of the Civil Veterinary Department should be enlisted in this question. Circulars were also sent to Sanitary Commissioners and to Health Officers, as these sometimes control the meat inspection, and I was able to visit personally a considerable number of Districts.

In Burma the Superintendent of the Civil Veterinary Department (Colonel G. H. Evans) reports that these worm-nodules "are pretty frequently present in oxen and buffaloes," but no details are forthcoming: in Assam, "they have not been observed"; similarly in Bengal. From Bihar and Orissa no information is available. In the Madras presidency, the Civil Veterinary Superintendent (Mr. Ware) was able to secure for me on two occasions specimens from

Indian bullocks—and I am informed by Mr. J. A. Valladares that he had found them in five bullocks at Madras previously to my visit.

In Ceylon, on my making enquiries, the Government Veterinary Surgeon, Mr. G. W. Sturgess, was able to obtain specimens from both *Bos indicus* and *Bos bubalis* killed in the local abattoirs, these nodules being evidently endemic in this Island. On examination of them in his laboratory, I found, although there were two or three living nodules from old cattle, most of them, large or small, were much caseated or calcified, or nearly absorbed.

Central Provinces and Berar.—I am indebted to Mr. J. A. Valladares, Deputy Veterinary Superintendent at Nagpur, for a number of specimens from four localities in this part of Central India, two being in the far North of the District, though in other localities in this district, where search was made, they were not obtainable. In each case they were found 1-3 in number, in the brisket and in old cattle. Once only were as many as eight nodules, all small in size, observed. In the four localities where careful observation was made and statistics were kept, only six animals were found affected out of a total of 1203 examined—though it is stated that in general "the existence of worm-nodules is fairly common in the Central Provinces."

United Provinces of Agra and Oudh.—The very careful investigations made, in response to my requests, at slaughter houses and meat drying factories, under the direction of Major J. D. E. Holmes, C.I.E., Imperial Bacteriologist, and of Mr. C. W. Wilson, 2nd Civil Veterinary Superintendent of these provinces (who most kindly set apart an officer especially for the purpose) have resulted in the finding of these worm-nodules in a great part of the area concerned from Bareilly and Shahjahanpur in the North to Jhansi and Lalitpur in the South, and from Aligarh and Agra in the West to Unao in the centre, and it is probable that they are even more widely distributed through this region than as yet discovered. I am informed by Mr. Wilson that these nodules have been known to exist here, although the fact had not previously been recorded. They are found both in *Bos indicus* and in *Bos bubalis*.[1] In cattle they occur the more usually about the base and side of the neck, but most commonly under the skin and in the intercostal spaces near the sternum, "between the 3rd and 13th ribs on the external oblique and pectoral muscles." In frequency affected cattle varied from 20 per cent. of the animals killed at the slaughter house and

1 See Addendum I.

meat drying factories at Bareilly to about 2 per cent. in other districts. Most usually only 1, 2 or 3 are present in each host, but occasionally from 6-10, or even up to 15 and 20, are seen; the animals available for examination were sometimes as young as five or six years, but as usual here, mostly older, e.g., 17 to 20 years. The nodules were found in all ages, but were more numerous in the older animals; calcification was often considerable.

In buffaloes[1]—and they are found in these in all districts and at Agra more commonly than in cattle—the nodules are found "adherent to the skin, which becomes thin and hairless just over these nodules, so that the skin is cut when they are dissected out. The worm-nodules among buffaloes are more red than those among oxen, which are white ones." As in the case of cattle, they are generally attached to the right and left of the sternum at a distance of two or three inches, sometimes in "large numbers, especially in thinner animals," the size of the nodules varying from that of a pea to a pigeon egg. Again the animals in which they were found were 17 and 18 years old.

The localities whence the Indian cattle carrying these nodules were derived, agree in being normally very dry and hot ,e.g., "The climate of Jhansi, as might be expected from the rocky nature of the ground, the rapid drainage, the absence of high jungle, and the general depth of the water level, is characterised by exceeding dryness, and by heat considerably above the average of the province" —which is exactly the reverse of the more or less swampy conditions found wherever the nodules are known in Java, and might at first sight be considered to exclude the possibility of any necessity for the presence of water, either directly or indirectly, for the completion of the life history. But as we find that the soils in these parts of the United Provinces are either black cotton soils, which "in season of heavy rainfall rapidly become over-saturated," or else chiefly very good loamy soils, the conditions seem to be present which would allow of the occurrence of standing water in certain seasons at least—quite sufficient for the infection of cattle or buffalo, if such be associated in any way with the method of infection or transmission.

Before leaving this part of India, it is well to record the experience of Mr. S. H. Gaiger, at one time Parasitologist to the Imperial Bacteriological Laboratory, and now of Lahore. In the course of the post mortems conducted by him at the laboratory at Muktesar

1 See Addendum 1.

as well as elsewhere, in spite of the most detailed examination of all parts of the carcases, in the endeavour to find any new parasites, never once had he come across these nodules, or anything resembling them. The inference can only be that if these nodules be present at all in the hill cattle, which are chiefly used at the serum laboratory, they are very rare indeed, a deduction which is in harmony with Lingard's statement (1905, p 36-37) in connection with the occurrence of aortic worms in cattle, that he found only three animals infected out of 2000 autopsied.

Punjaub.—During my enquiries as regards this province, I found from Colonel Pease, Director of the Veterinary School at Lahore, and his staff, to whom I am indebted for their active interest, that worm-nodules had never been recognised in the Punjaub, and that they were very doubtful about their occurrence. In communications seven months later, Colonel Pease informed me that he had since found that the nodules are known to the butchers, but are very uncommon. After considerable difficulty he had managed to obtain two or three from the brisket of a five-year-old buffalo, and five from the brisket of a eight-year-old cow, the latter being the result of special examination of 120 cattle (=.83 per cent.).

Sind, Baluchistan and Rajputana.—The Acting Civil Veterinary Superintendent (Mr. E. S. Farbrother) of this area writes that he has "made investigations in Sind, but can find no evidence of the presence of worm-nodules in cattle in this part of India."

Bombay Presidency.—In spite of numerous enquiries in all directions which might possibly yield any results, I have been unable to hear of any instance of the occurrence of these nodules in this Presidency, either from Veterinary Surgeons (one of whom, Mr. Sowerby, of Bombay, has been watching carefully for cases since my visit, without result), Inspectors or Superintendents of Abattoirs.

I was not able to find any evidence of the occurrence of *Onchocerca fasciata* in camels in India, other than as already found by Mr. Leese in the Punjaub, and recorded by Railliet and Henry (1910, p. 248).

In India we find the aortic worms represented so far as I have yet been able to find, by *Onchocerca armillata* only. This has already been recorded by Lingard (1905, p. 27) from the aortae of cattle and buffalo—in 70 per cent. of "plains cattle," and in 15 per cent. of "hill cattle."

Egypt and the Sudan.

So far, worm-nodules in bovines have only been recorded for Africa, as present in parts of Algeria and Tunis, by Professor Neumann, who has described *Onchocerca gutturosa*, Neumann, 1910 (1910, p. 270) from the region of the cervical ligament in the neck of cattle killed at Constantine and at Tunis. I was informed by Mr. F. E. Mason, Government Veterinary Pathologist, Cairo, that worm-nodules are present in the subcutaneous connective tissue of any part of the body, but especially along the sides of the neck in the Egyptian Belady or village cattle. These animals, which are prevalent as far south as Wady Halfa, have a more gently curving, dome-shaped hump, somewhat more forwardly placed than in the case of the Sudanese cattle. Specimens from these are under promise to me; in the meantime I am unable to say whether they are similar to *Onchocerca gutturosa*, or to the Indian form, or even a different species from either of these. *O. gutturosa*, as described by Professor Neumann, forms flattened nodules up to the size of the palm of the hand, situated in connective tissue on the inner face of the cervical ligament, in the region of the 2nd or 3rd dorsal vertebrae. These worm-containing nodules are very similar to those of *O. gibsoni*, though differing in location, and formed by another species of worm.

The Sudanese cattle have a more backwardly placed hump, shaped more like that of *Bos indicus*, of India, and are more prevalent south of Wady Halfa. So far as I have been able to obtain any evidence, either at the time of my visit or since from the Director of the Veterinary Laboratory at Khartoum, the nodules are unknown in these Sudanese cattle, and also in the buffalo of these countries.

Mr. Mason also informed me that the subcutaneous worm-nodules of camels in Egypt, recorded by himself as "present in subcutaneous positions, and similar to those found by Cleland in camels in Western Australia," but recorded nevertheless under the name *O. gibsoni* (1912, p. 97), while found chiefly along the side of the neck, are also found over the quarters, then on the head, and sometimes in the subcutaneous connective tissue of any part of the body. As no specimens have yet come to hand, I am unable to state whether or not these are caused by *O. fasciata*. He has also recorded the presence of "mature filarial worms, presumably *Filaria evansi*, in the blood-vessels of the lungs, testicle, and in the vas deferens of camels" in Egypt (1906, p. 120, and 1911, p. 329).

Europe.

Investigations were continued in Italy, Austria, Switzerland, Germany, Denmark, France, and Great Britain, but all enquiries from those under whose notice the existence of worm-nodules, such as *O. gibsoni* must have come, did they occur, were met with negative replies. The genus *Onchocerca* is, however, represented in every department of France by a species (*O. bovis*, Railliet et Henry, 1912) (see Piettre, 1912, p. 509), which is found in as many as 95 per cent. of cases inspected at Les Halles Centrales in Paris. Here M. Piettre, their discoverer, who is in charge of the Veterinary Laboratory, enabled me to see several examples of this infection. These are, however, as already described by M. Piettre (Oct., 1912, p. 537, etc.), much more like *O. reticulata* of the horse in their manner of occurrence, no nodular formation taking place. As recorded and shown to me by him, *O. bovis* occurs almost exclusively in the region of the femoro-tibial articulation in the thickness of the internal and external articular ligaments, and in the tendons, generally nearer the tibial than the femoral surfaces. Two to five worms, males or females, or both, lie coiled in and out of the fibres, in the thickness of the ligaments and tendons, causing their degeneration, though free parasites may be found between the synovial membrane and the tendons. I have, therefore, not been able to find any evidence of the indigenous existence of these worm-nodules in Europe.

United States of America.

In a country of such extent as this, having a great range of latitude and of climate, many of the Southern States occupied in cattle-raising being similar in latitude to districts in the Eastern Hemisphere where these nodules are found, it is credible that one should find some form of worm-nodule similar to those found in the latter hemisphere.

Moreover, considerable interest attached to enquiries here on account of the importation of "Brahman cattle" into South Carolina in 1849 (Mohler and Thompson, 1911, p. 84), into Southern Texas about the year 1880 (loc. cit., p. 81), and again in 1906 (loc. cit., p. 82-3), some at least being derived from districts in which worm-nodules are now known to exist.

The chances of discovery of anything of this kind here are very considerable, in view of the admirable work of the Federal Bureau of Animal Industry at Washington, D.C.—the Zoological division

of which pays special attention to the parasites of domesticated animals—the widespread system of meat inspection by properly qualified Veterinary officers, and the numerous Agricultural Experimental stations throughout the States.

Hitherto, a species *Filaria lienalis* (possibly to be referred to the genus *Onchocerca*) has been described by Dr. Stiles in 1892 from the capsule of the spleen of cattle in U.S.A., but nothing comparable in position and nodule structure with *O. gibsoni* has ever been recorded from that country, nor in my visits to the Bureau of Animal Industry, or the State Veterinary Schools of Pennsylvania, Ohio, or the Agricultural Experiment Station of Illinois, was I able to hear of anything further. To test their possible existence in the most probable district, the Chief of the Bureau of Animal Industry (Dr. Melvin) and the Chief of the Zoological Division (Dr. B. H. Ransom) kindly undertook to have investigations made to determine definitely whether or not these worm-nodules exist in the descendants of the imported animals referred to above, and whether it has spread at all to the local breeds. As they have not so far, however, been recognised by the Veterinary Inspectors of this country, one may well assume that they are not present there.[1]

I was, unfortunately, unable to visit South America, and no definite information is yet forthcoming therefrom. However, a careful investigation has been very recently made into the cattle industry in South America by two independent and eminently qualified officials—Dr. Melvin (1914, p. 347) from the United States and Mr. Dunlop Young (Chief Meat Inspector, London) from England (1914, p. 522). Neither of these observers have any evidence of the existence of worm-nodules in South America, and such must surely have come under their notice, especially under that of Mr. Young, who has been familiar officially with their occurrence in Australian cattle. One may, therefore, conclude that so far they are absent from South America.

It is, however, interesting to note that in 1906 (Gunn, p. 31) 200 young Ongole cattle were taken from the Madras Presidency, where these nodules are now known, to Brazil, so that it will be well to follow the effects of this importation in this respect.

PART II.—SYSTEMATIC.

The question of the specific identification of the nematode causing the worm-nodules found in Indian cattle has been a matter of considerable difficulty in some respects—chiefly in view of the

1 See end of Addendum 2.

marked range of variation in size in certain structures. The almost certain derivation of the Australian *Onchocerca gibsoni* from cattle imported from India or Malaysia, coupled with Dr. Leiper's identification (1911, p. 10) of the parasite found by Ford in the Malay States in 1904 as *O. gibsoni*, and the assertions of the same identity in the case of the Javan parasite by other workers, made one naturally expect to find the Indian species the same also. The absolute similarity of the position and manner of occurrence of the nodules in the body of the host and of their macroscopic structure still further strengthened this expectation. However, during the microscopic examination of one or two nodules as a matter of routine identification, I was impressed by the variation shown by them in some details of structure outside the range previously recorded for *O. gibsoni*, and accordingly dissected more nodules. From these I obtained five females (four complete in essential parts) and six complete males.

Onchocerca gibsoni has been already described by Dr. Gilruth and myself in detail in a Bulletin issued by the Commonwealth of Australia, as well as by Drs. Cleland, Johnston, Leiper and Breinl (see Bibliography). After careful measurements and comparisons with this and other forms, I have been forced to the conclusion that the form found in cattle in India is to be regarded as a different species, which I have called *O. indica*, and a specific description of which is hereafter given; nevertheless I have no doubt whatever as to the origin of these forms from one another, or else of both from a common ancestral form. In view of this it is doubly disappointing to me not to have yet received other material from Javan and Egyptian cattle and buffaloes, and also from Malaysian and Indian buffaloes[1] as this (especially that from Javan cattle) would probably throw further light on the question. Nevertheless it seems desirable to publish what I can up to date, and add to it later on. I have a certain amount of material from some of these hosts and localities, but, as previously stated, it was in such a condition as to be useless for this purpose. While this report was being completed I had the gratification of receiving specimens from Mr. Ford from an Indian bullock in Malaysia, and from Siam cattle, which will be referred to later.[2] The nodules found in cattle (*Bos indicus*) in India resemble exactly in macroscopic appearance and position in the body those of *O. gibsoni* found in cattle (*Bos taurus*) in Aus-

1 See Addendum 1, *re O. indica* in *Bos bubalis*.

2 See Addendum 1, *re O. indica* in *Bos bubalis*.

tralia.[1] They are more frequently flattened like a broad bean in the former than in the latter, much as in *O. gutturosa*, due naturally to compression between the muscles and between them and the skin. I have not seen any so large as those sometimes found in *O. gibsoni*, nor any with anything approaching the great thickness of fibrous tissue, such as occasionally occurs in the latter. A thickness of 5 mm. of fibrous capsule is abnormally great in *O. indica* in cattle, 2 to 3 mm. being the more common. A larger proportion of nodules of *O. indica* seen by me are calcified or caseated, due undoubtedly to the fact that practically only aged cattle are killed in the country whence these come. The whole tissue of the nodule is often permeated with larvae, even in cases where mature worms show no larvae in the genital tubes; also larvae (.12 to .16 mm. long) are to be found on the periphery of the nodule, and sometimes thickly in the loose connective tissue on the surface of the nodule.

The connective tissue trabeculae, which form the walls of the network of tunnels, in which the worm lies, resemble exactly in nearly every case those of *O. gibsoni*, but in two instances (see fig. 4) one was surprised to find within the dense fibrous capsule, which was 1.5 and 2 mm. respectively in thickness, the worm lying quite freely in the interior, with only one or two delicate connective tissue strands 2 to 3 mm. long, in place of the intricate fairly substantial network otherwise present. Evidently either an inexplicable inhibition of fibroblasts had taken place in the interior during the development of the nodule, or probably, some unusual degenerating factor had been at work, since in one case, the internal structure of the anterior part of the body of the female was almost undecipherable, while that of the male was also affected.

The simple relationship found in *O. gibsoni* between the heads of the male and the female does not so frequently obtain here. There is always, however, a certain close association (see figure 3), and intertwining of these and of the tail of the male, which are generally to be found on one of the flattened surfaces, the body of the male sometimes coiling about in close proximity at several points to the other flattened side.

In reference to the numbers of males and females associated together in each nodule, it is interesting to note that although Breinl (p. 9) has noted the occurrence of two males with one female in the case of *O. gibsoni*, no one else has hitherto observed this condition, while in *O. indica*, of the four females obtained entire,

1 See Addendum 1, *re O. indica* in *Bos bubalis.*

two nodules had one male, and the two other nodules each had two males. In the other nodules dissected no male was found at all.

In structure, the worm very closely resembles *O. gibsoni*, to which it has undoubtedly close affinity, and in view of the detailed descriptions of that worm already published (and referred to above) it is unnecessary to repeat here a minute general description. I have therefore contented myself with a statement of the specific characteristics of the Indian worm, and a careful comparison with other allied forms as indicative of the reasons for the establishment of a new species. Incidentally, light is thrown on one or two points of general interest as regards the specific diagnosis of Nematodes.

The characteristics of this worm may be summarised as follows (cf. Tables 1, 2, 3, and Figures 5, 6, 7, 8, 9), the variations being discussed in detail later.

Onchocerca indica, n. sp.

Male.—3.38 to 9.3 cm. long (average 5.69 mm.); diameter of central portion of body, .175 to .220 mm. (average, .198 mm.), tapering to each extremity. Anterior end straight and without interruption, posterior end often spirally coiled, having a cloacal swelling on which the cloaca opens, behind which the tip of the tail is generally bent sharply towards the ventral surface, forming a hook. Cuticle, .003 to .004 mm. thick in the central region of the body, where also it has regular rounded transverse ridges, the depressions between which are .005 to .006 mm. apart at the maximum, these ridges becoming smaller and less conspicuous as they approach the two ends, where they are absent; finer striae were not detected. Mouth terminal with three slightly marked lips and three papillae (not always easily seen) close behind the level of the opening. Oesophagus long, from over .847 to 1.22 mm. (average, over 1.051 mm.), thick-walled, .031 to .039 mm. (average, .036 mm.), and generally with a well-defined bulb (or "cardia"), .062 to .069 (average, .064) mm. long, and .047 to .060 (average, .053) mm. wide, at the junction of the oesophagus, with the typical thin-walled, straight intestine. Nerve ring surrounds oesophagus usually at .188 mm., though sometimes at .172 mm. (average, .182 mm.) from the anterior end, and where seen the excretory pore appeared to be situated at .219 to .282 (average, .250) mm. from the anterior end. Cloacal opening at .062 to .086 (average, .07) mm. in front of the tip of the tail, the diameter of the body at the level of the opening being .042 to .062 (average, .053) mm. Anal papillae somewhat variable, generally eight or nine pairs in number, but sometimes

asymmetrical, their range being as follows:—*Right*—preanal 1, par- (or ad-) anal 4 (or rarely 3), postanal 1, precaudal 1, caudal 1 to 2. *Left*—preanal 1, paranal 3 to 4, postanal 1, precaudal 1, caudal 1 to 2. Two unequal spicules of characteristic shape, the longer .207 to .274 (average, .257) mm. long, and .009 to .012 (average, .011) mm. in diameter at middle of length, curved in harmony with the body curve, the proximal termination being enlarged and funnel-shaped, and the distal termination pointed or rarely slightly bifid. Midway the median channel of the distal portion of the long spicule opens obliquely forwards and outwards to its surface. Short spicule .08 to .094 (average, .087) mm. long, enlarged proximally and flattened somewhat in the greater part of its length, being .006 to .012 (average, .007) mm. in its less diameter, and .012 mm. in its greater diameter, its distal termination having a shoe-shaped enlargement for the guidance of the long spicule. On one occasion the short spicule was missing, and no evidence could be seen of its having previously been present.

Female.—May reach at least 100 cm. in length; diameter of central portion of body .38 to .63 (average, .47) mm., tapering at each extremity, both ends being straight and uninterrupted. Cuticle .02 to .024 mm. thick in the central region, and thickened for greater part of the length of the body into prominent wavy ridges, which may be as much as .138 mm. apart; generally in one continuous spiral, with occasional gaps at one or other side, and also occasionally a double spiral may be found; no network is present, and the spiral ridges are gradually lost anteriorly and posteriorly; no fine transverse striae could be seen. Mouth terminal, with three very small lips and three papillae, but no separation of the head from the body, and no cervical swelling. Oesophagus long, 1.1 to 1.44 (average, 1.23) mm., and equally thick walled with that of the male, .031 to .034 (average, .032) mm. in diameter. Bulb (or cardia) more frequently indefinite than in the male, but when present is .062 mm. long, and .045 to .055 (average, .050) mm. in diameter. Nerve ring at .188 mm. from the anterior end; excretory pore not seen. Anus at .125 to .232 (average, .187) mm. from the posterior end. Vulva in mid-ventral line, generally on a slight swelling, at .55 to .75 (average, .63) mm. from anterior end, leading internally into a thick-walled sometimes twisted vagina. Segmented ovum .026 x .017 mm., eggs containing fully developed larvae .0251 to .0329 mm. long, and .0172 to .0251 mm. wide; larvae just free from egg, which has a very thin shell, .12 to .196 mm. long, and .0021 to .0024 mm. in

diameter; all stages up to free embryos being found in the genital tubes of the female larva, with very bluntly truncated head, and gradually tapering to a very long fine point posteriorly, no sheath being observed. (Larvae were insufficiently well preserved to allow of accurate observation of histological structure, being also easily broken in making smears.)

In a previous paper on *O. gibsoni* (Gilruth and Sweet, 1911) the very considerable amount of variation in important structures was pointed out, as had also been done by myself on two or three previous occasions (e.g, see Sweet, 1910, p. 243 et seq., and p. 247 et seq.) when describing new species, which, so far as I am aware, have not yet been recorded from elsewhere, and which are undoubtedly and most naturally closely allied to analogous forms in the same host in "older" countries. It would seem that the transference in these latter cases of the domesticated host from its older habitat to a new environment in Australia has fairly quickly influenced the structure of some of the contained parasites to an unexpected degree. On the other hand, although in most cases the older workers gave no indication of any variability in measurements given, it is probable that a considerable amount of variation exists even in well-known species elsewhere. In view of this it is of interest while considering the value of measurements in specific diagnoses to compare work summarised in a paper by Fracker (1914, p. 22), in which he seeks "to ascertain the extent to which the proportions of the worm (*Oxyurias vermicularis*) were constant, and the parts which undergo the greatest variation," considering especially the use of the formula suggested by Cobb in 1890, and since invariably used by him. Fracker concludes that while "an individual should never be identified on the basis of the formula alone, or of the proportions alone," "the proportionate size of the organs in the Nematoda is an important factor in their identification, and should be stated in any description of a new species." With these conclusions, in so far as they emphasise the necessity for a statement of measurements, most workers in the group of Nematodes will agree, in view of the paucity of marked specific characters. Curiously, however, in the case of the two species of Onchocerca which I have studied in this special connection, measurements proportionate to the length of the body even of the male, such as are emphasised by Fracker, are useless for the purpose of specific diagnosis, such measurements having no relation to one another, while within a stated range, there is a marked similarity in certain absolute measurements, quite irrespective of the length of the

animal, and such variations as do occur, are independent of the size of the worm. All measurements given in the paper on *Onchocerca gibsoni* previously quoted (Gilruth and Sweet, 1911), and those given here for *Onchocerca indica*, have been made under identical conditions—the specimens being cleared in carbolised absolute alcohol, just before measurements were made with a standardized screw micrometer eyepiece—so that in comparison of these two sets of figures all extraneous influences are eliminated, except any differences which might be due to a different preserving fluid. Since, however, the action of the above clearing fluid freshly applied in the way indicated is to "plim" the body of the worm into its apparently normal condition as when living, I think this may be ignored, and we may regard the figures given as strictly comparable. Reference is made to figures given by other workers as indicated, since although perhaps not strictly comparable with the two sets given by myself (on account of the slightly varying amount of swelling or contraction caused in certain parts by different clearing reagents), they may at least be taken to indicate that variations in excess of those present in the worms examined by me, were encountered by these workers, so must be taken into account in separating two species so closely allied as the two under consideration.

Reference to Tables 4 and 5 included herein will facilitate such comparison. As will be seen (Table 4), the range in length of mature *male* worms is considerably greater than in *O. gibsoni*, *O. gutturosa*, or *O. bovis*, the other forms of this genus occurring in the connective tissues of cattle, the average length also being greater than in those species. Further, the worm is markedly stouter than any others, the specimens of *O. indica* exceeding in average diameter the stoutest of *O. gibsoni*, both anteriorly and in the middle part of the body. The stoutness, however, bears no relation to the length of the worm, as will be seen on glancing at Bii, and Dii, and E in Table 1. In spite of this, the variation in position of the nerve ring from the anterior extremity is exactly the same as found by ourselves and Cleland and Johnston in *O. gibsoni*, though greater than that recorded by Breinl, and less than by Leiper. Rather unexpectedly, moreover, in the two longest specimens of *O. indica*, I find that it is slightly further forward than in the others, though one would naturally have thought to find the reverse. The oesophagus of the male again always exceeds in length the highest range given for *O. gibsoni* by all workers, except Breinl, and, as a rule, that found in *O. gutturosa* or *O. bovis*, while in diameter it greatly exceeds

that of other forms (with the same exception), being often twice the thickness in those forms. The oesophageal bulb or "cardia" also is unusually conspicuous, occupying on an average the terminal .064 mm. of the oesophagus. In specimens of *O. gibsoni* examined by me, it was not seen, though from Leiper's and Breinl's descriptions of the occasional thickness of the posterior end of the oesophagus, something of the sort was evidently present in some of their specimens, this probably accounting for this exception in regard to the thickness of the oesophagus mentioned above. A glance at the averages of length and diameter of the oesophagus of *O. indica* and *O. gibsoni* will show the extent to which that in the former exceeds that in the latter. The Cloacal opening is also often further from the posterior end than in specimens of *O. gibsoni* examined by me, though the range in *O. indica* corresponds approximately with that given by other workers for *O. gibsoni*. The spicules show a certain amount of variation from other forms, most marked, however, in the case of the long spicule. This in general exceeds that of any of the other forms, the range of which it overlaps, except the greatest length of *O. gutturosa*, while its lowest range only slightly overlaps the highest range of *O. gibsoni* (Breinl)[1] and of *O. bovis*. Further, the average length of the long spicule of *O. indica* is considerably greater than the greatest length given by any one for *O. gibsoni;* though the range of thickness of the long spicule in *O. indica* is included within the total range found in *O. gibsoni*. Not only does the long spicule most nearly approximate that of *O. gutturosa* in range of length, but also in the fact that the long spicule of *O. indica* sometimes appears bifid as in *O. gutturosa*. The range in length and diameter of the short spicule agrees approximately with the total ranges found by others and myself in *O. gibsoni*, though the average, both of length and diameter of the short spicule, is greater than the average of all forms of *O. gibsoni* described. The anal papillae also show considerable variation, as was pointed out by us to occur, though to a less extent in *O. gibsoni*. The highest number of papillae described by any observer (with the exception mentioned immediately) for the latter species, was seven pairs—one preanal, three ad- (or par-) anal, one post-anal, one precaudal, and

1 If the figures given by Dr. Breinl for his male specimens of *Onchocerca gibsoni* be analysed, it will be seen that the three individuals in which the length of the long spicule overlaps the lower end of the range found in *O. indica* do not show the concurrent characteristics found in *O. indica*, except that in one case (No. 19), a length of oesophagus (1.074 mm.) which is unique and extraordinary for *O. gibsoni*, is found in a worm having a length of .210 mm. for the long spicule. Apart from this one worm there does not appear to be any regularity of variation in *O. gibsoni*, in the features referred to, as characteristic of *O. indica*. A study of these tables will emphasize the extreme and irregular variability of Australian specimens of *O. gibsoni*.

one caudal (the latter three being grouped together in those descriptions as three post-anal). In one specimen seen by Breinl, and one side of one specimen from our material, an additional papilla was present anterior to the usual preanal ones, making eight in those two isolated cases. The exact way in which these occur in the six male specimens of *O. indica* referred to is shown in Table 2 and Figure 9, where it will be seen that, with the exception of one side in one case, the smallest number of papillae is eight on each side, while nine are present nearly as often as eight; and, also, the arrangement is different from that of *O. gibsoni*, the additional papillae being adanal and caudal in position, not preanal. It is also interesting to note the occasional occurrence of only three adanal papillae, as is characteristic of *O. gibsoni*, though in two out of these three occurrences the number of postanal (four) characteristic of *O. indica* are certainly present; in the other case I could not be positive on the point. Transverse ridges are present at a distance of .005 to .006 mm. apart, cf. .0045 to .0060 mm. in *O. gibsoni* (.045 mm. given by Leiper must surely be a printer's error for .0045), and .005 to .006 mm. in *O. bovis*, and contrast Neumann's measurements for *O. gutturosa*.

In the case of the *female* worms (see Table 5) the length and thickness of *O. indica* falls within the range found in *O. gibsoni*, with the exception of the tail, which is markedly thinner; the average thickness is, however, distinctly less in *O. indica* (except in the middle of the body, while the average diameter of the tail of *O. indica* female is less than the minimum given for the tail of *O. gibsoni* female. The position of the nerve ring is constantly the same as in the highest range given for *O. gibsoni*. The length of the oesophagus in the four females of *O. indica*, in which it was measurable, always exceeds that of *O. gibsoni*, with the exception of two instances quoted by Breinl. In thickness it is fairly constant in *O. indica*, and within the range found in *O. gibsoni*. The average length and thickness is much greater in *O. indica* than in *O. gibsoni*. The position of the vulva and that of the anus varies much less than in *O. gibsoni*, and like each of the other species of Onchocerca, they fall within the range found in *O. gibsoni*, though their average positions are much nearer the tip of the head and tail respectively than in that species. The egg, when segmentation is complete, is similar in size to that of *O. gibsoni*. Eggs containing fully developed larvae are smaller than those of other species, and the larva when just freed from the egg shell is distinctly shorter, .12 to .196 mm. being the length in *O. indica*, this range over-

lapping that of *O. gutturosa* only. In diameter it is often only half that found in other forms. The cuticle in the female *O. indica* is distinctly thinner than in *O. gutturosa*, but twice at least as thick as in *O. gibsoni*. Moreover, the ridges of the cuticle so characteristic of the female *Onchocerca* are further apart in the middle of the body than in *O. gibsoni*, and are often much more prominent.

Comparative measurements in some of these cases may possibly be regarded as misleading, and further observations may render the range in size much nearer, still the greater number and different arrangement of the anal papillae, and the greater length of the long spicule, the generally thicker head of the male and thinner head and tail of the female, and the usually longer oesophagus in both male and female seem to call for the separation of the new species, which it will be seen is in some respects intermediate between *O. gibsoni* and *O. gutturosa*.

This being established, one expected to find, even more than a possible geographical delimitation of the species, a definite relation to the special host; and in examining the material which so recently arrived from an old Indian bullock (*Bos indicus*) from the Malay States, and from Siam humped cattle (*Bos indicus*) freshly imported into Kuala Lumpur (F.M.S.) for slaughter, I certainly expected to find that these nodules, especially in the former case, were *O. indica*, and in the latter either that, or quite possibly a form intermediate between it and *O. gibsoni*, and perhaps rendering the separation of the former from the latter untenable. To my surprise, the nodules from all of these contained worms belonging without any doubt whatever to *O. gibsoni*, the measurements, etc., of those parts mentioned above on which the separation is based being almost invariably those of average specimens of *O. gibsoni*, or even nearer the limit of the range in *O. gibsoni*, away from that which approaches the range of *O. indica*.[1] This fact corroborates some years after, and on varied material from *Bos indicus* from Siam as well as Indian bullock (*Bos indicus*) long domiciled and possibly bred in Malaya, the identification by Leiper of Ford's original material, also from an old Indian Zebu in Malaya. Johnston (1911, p. 223) quite obviously misinterprets Leiper in stating that he identified "aortic worms" in Malayan buffaloes recorded by Ford, 1902 (not 1903) as *Onchocerca gibsoni*. Leiper's identification (1911, p. 10) was of the material referred to by Daniels (1904, p. 17) as coming from "near the shoulder in bullock beef." For purposes of comparison I

1 See Addendum 1.

append in Tables 6 and 8, the measurements made of the worms found in these Siamese and Malayan nodules. One nodule from the Indian bullock was particularly interesting, as it was found to contain two females, 4 iv. and 4 v., and three male worms, 4 i., 4 ii. and 4 iii. No. 3 was also from the same animal, Nos. 1 and 2 being from the Siamese bulls. Also, in Table 7 and Figure 10, I have shown the number and arrangement of the anal papillae, which are emphatically not those of *O. indica*, and which vary considerably among themselves. It is interesting to note in Fig. 10 (3, left side) one solitary and unilateral example of four adanal papillae (cf. the usual four adanal papillae of *O. indica*), though even here the total number of papillae is only seven on that side.

CONCLUSIONS.

It is evident then that we have in India itself a different species of nodule-forming worm from that present in the same host species in Siam and Malaya, and in *Bos taurus* in Java and Australia. The exact geographical limitation of *O. indica*, I am unable to state further, and it is more than possible, as hinted before, that with additional material from Burma and Bengal, or elsewhere, one may find a complete mergence of the one species into the other in view of the remarkable extent of variation in each, but especially in *O. gibsoni*, and of the already known overlapping in some measurements. Still there is the most definite and constant means of separation in the association of a shorter long spicule, with a smaller number and different arrangement of anal papillae in *O. gibsoni*.

It would appear that *O. indica* is the true species of the Peninsula of India, and *O. gibsoni* as seen in these Siamese and Malayan cattle that of the Malay Peninsula, and immediately adjacent countries. Further, either (1) the *O. gibsoni* seen in Australian cattle and that of the Malayan and Siamese cattle are undergoing a process of modification parallel with one another, from *O. indica*, or (2) *O. indica* has arisen from the Malayan *O. gibsoni;* or (3), and most probably, both *O. indica* and the Malayan *O. gibsoni* have arisen together from the original form, and from this Malayan form either directly or indirectly the Australian form (introduced at least 70 years ago) has continued to be modified, its variability being quite remarkable. Although the greater length of the large spicule of *O. indica* is fairly constant, and its shorter length in the Malayan *O. gibsoni* is likewise fairly constant, the anal papillae

certainly show some slight indication of a not very distant common ancestry, and there is no doubt in my mind that the host animal of the original Asiatic nodule-worm will yet be found in the Indo-Malayan gaur or wild ox (*Bos* (*Bibos*) *gaurus*), or its variety, the Seladang, or the nearly allied species, the Javan Bantin.

It is to be noted further that in the regions where these nodules occur in Australia, the number of animals affected is much greater than in similar parts of India and apparently of Malaya. This greater frequency in *Bos taurus* is undoubtedly due to its having less resistance to the development of the parasite than has *Bos indicus*, which is at least more closely allied to the presumptive original host. As to Java, I have been unable to obtain definite information as to the relative frequency of the nodules in introduced or locally bred *Bos taurus* or *Bos indicus*.[1] One is justified in the light of the evidence in expecting to find in Javan nodules characteristics closely similar to those of the Australian form, though whether they have been introduced into Java from Malaya or from India, is as yet unknown, though one would judge the former to be the more probable. It is, of course, quite probable if the Indo-Malayan gaur were the original source of infection that also the Seladang of Malaya was and is likewise infected, and that this was the immediate source of the infection of the Malayan cattle. Whether the Javan Bantin was also infected, either originally or secondarily, or whether the infection came there from the Malay Seladang or from Malay cattle, we cannot yet tell.

The greater variability of the Australian form is only analogous to what I have pointed out previously (vide supra), that the tendency is when parasites are introduced into this continent, even in their normal European (or other) domesticated host, for considerable variation to take place at times resulting in the formation of what appears to be a distinct and new species.

It is greatly to be regretted that material is not yet forthcoming from the Malay Archipelago for close comparison with these forms, as it would appear from the above that the entrance of the nodule-worm into Australia cannot be credited to the introduction of Indian cattle into the Northern Territory, but rather to that of cattle from further East, and so quite probably from Timor—as previously emphasised—sometime between 1824 and 1840. It is to hoped that information and material from Timor may soon be forthcoming, in which one may expect to find a link between the Malayan and the Australian *O. gibsoni*.

1 See Addendum 2.

The contention of Dr. Gilruth and myself (1912, p. 24) that the buffalo was probably not the means of introduction—since the buffalo hunters of the Northern Territory (who used the brisket for food and the skins for export) have never seen these nodules—is strongly supported by the fact that both in Java and in India, whence buffalo have been imported into Australia, although nodules are present, they are found closely attached to the skin, a fact which was unknown to us at that time.[1]

The intermediate character of *O. indica* in some respects between *O. gibsoni* and *O. gutturosa* suggests the possible origin of the latter form from *O. indica* at some earlier period in some way not yet known.

No definite evidence is forthcoming from any source as to the life-history of these forms.

SUMMARY.

1. Worm-nodules in the connective tissues, caused by species of Onchocerca are now known to exist in cattle and associated animals as follow :—

Place.	Host Animal.	Previous record.	Present record.[2] 40-90%
Java	Bos taurus	O. gibsoni (De Does, etc.)	O. gibsoni (?)
,,	Bos indicus	—	O. sp. (?)
,,	Hybrids of above	—	O. gibsoni (?) (subcutaneously)
,,	Bos bubalis	—	O. sp. (?) (subcutaneously)
,,	Bos banteng	—	—[3]
Sumatra	Bos taurus	—	O. gibsoni (?)
,,	Bos indicus	—	O. sp. (?)
,,	Bos bubalis	—	O. sp. (?) (subcutaneously)
,,	Bos banteng	—	—
Bali	Bos taurus	—	O. gibsoni (?)
Madura	—	—	—
Lombok	—	—	—
Timor	—	—	—
Poeloe Laoet	Bos indicus	—	O. sp. (?)
Philippine Is.	Bos indicus (?)	—	—
,, ,,	Bos bubalis	—	—

1 See Addendum 1.

2 The mark (?) in this column indicates that, although I have now evidence of the existence of the nodules as indicated, either the material available is useless for exact specific determination, or else material for this purpose is not yet in hand.

3 The mark — indicates that such nodules are as yet unknown in these cases.

Place.	Host Animal.	Previous record.	Present record. 40–90%
Hawaiian Is.	Bos taurus	—	—
„ „	Bos bubalis	—	—
Singapore	Bos indicus	—	—
„	Bos bubalis	—	—
Kuala Lumpur	Bos indicus	O. gibsoni (Daniels, Ford, Leiper)	O. gibsoni
„ „	Bos bubalis	—	O. sp. (?)
Penang	Bos indicus	—	O. gibsoni
„	Bos bubalis	—	O. sp. (?)
Malaya	Bos taurus hubbacki	—	—
Siam	Bos indicus	—	O. gibsoni
Burma	Bos indicus	—	O. sp. (?)
„	Bos bubalis	—	O. sp. (?)
Assam	—	—	—
Bengal	—	—	—
Bihar and Orissa	—	—	—
Ceylon	Bos indicus	—	O. indica n.sp. (?)
„	Bos bubalis	—	O. indica n.sp. (?)
Madras	Bos indicus	—	O. indica n.sp.
„	Bos bubalis	—	—
Central Provinces and Berar	Bos indicus (.5%)	—	O. indica n.sp.
Central Provinces and Berar	Bos bubalis	—	O. indica n.sp. (?) (subcutaneously)
United Provinces of Agra and Oudh	Bos indicus (2–20%)	—	O. indica n.sp.
United Provinces of Agra and Oudh	Bos bubalis	—	O. indica n.sp. (?) (subcutaneously)[1]
Punjaub	Bos indicus	—	O. indica n.sp.
„	Bos bubalis	—	O. indica n.sp. (?)
„	Camelus bactrianus	O. fasciata (Leese, Railliet)	—
Sind, Baluchistan and Rajputana	Bos indicus	—	—
Sind, Baluchistan and Rajputana	Bos bubalis	—	—
Bombay Presidency	Bos indicus	—	—
„ „	Bos bubalis	—	—
Egypt	Bos indicus (?)	—	O. sp. (?)
„	Bos bubalis	—	—
„	Camelus dromedarius	O. fasciata (?) (Mason)	—
Sudan	Bos indicus (?)	—	—
„	Bos bubalis	—	—

1 See Addendum 1.

Place.	Host Animal.	Previous record.	Present record. 40–90%.
Algeria and Tunis	Bos taurus (?)	O. gutturosa (Neumann)	—
Italy	Bos taurus	—	—
Austria	„ „	—	—
Germany	„ „	—	—
Denmark	„ „	—	—
Switzerland	„ „	—	—
France	„ „	O. bovis (Piettre) not nodule forming	O. bovis
Great Britain	„ „	—	—
United States of America	„ „	O. (?) lienalis (Stiles) in capsule of spleen	—
United States of America	Bos indicus and hybrids	—	—
South America	Bos taurus	—	—
„	Bos indicus and hybrids	—	—

2. Allied parasitic worms are present as previously known in the main aortae of cattle and buffalo, as follow :—

Place.	Host animals.	Parasite.
Java	Bos indicus (rarely)	Elaeophora poeli
„	Bos bubalis	„ „
Sumatra	Bos indicus	Onchocerca armillata
„	Bos indicus (rarely)	E. poeli
„	Bos bubalis	„ „
„	Bos bubalis (rarely)	O. armillata
Malay States	Bos indicus	„ „
„ „	Bos indicus (rarely)	E. poeli
„ „	Bos bubalis	„ „
„ „	Bos bubalis (rarely)	O. armillata
Annam	Bos indicus	„ „
„	Bos indicus (rarely)	E. poeli
„	Bos bubalis	„ „
„	Bos bubalis (rarely)	O. armillata
India	Bos indicus	„ „
„	Bos indicus (rarely)	„ „

3. The new species herein described from cattle in India,[1] while overlapping in some respects the allied species *O. gibsoni* and *O. gutturosa*, differs from those, in the association in the male worm of a certain range of length of the larger spicule intermediate between those two species with a greater number of differently arranged anal papillae than is found in either of them, and from

1 And see Addendum 1, *re* its presence in buffalo in India.

O. gibsoni further in the thicker head of the male, the thinner head and tail of the female, and the generally longer oesophagus in both.

4. The limitations of these species appear to be geographical rather than otherwise:—thus, *O. gutturosa* is characteristic of Northern Africa, presumably in *Bos taurus; O. indica* is found in *Bos indicus*[1] in the peninsula of India, and *O. gibsoni* in *Bos indicus* in the Malay Peninsula, and as a very variable form in *Bos taurus* in Australia, and most probably the Malay Archipelago. The occurrence of such nodule-forming worms is probably much wider than is at present suspected.

5. The evidence supports the theory that worm-nodules were introduced probably by cattle from the Malay Archipelago, and not by cattle from India, and therefore almost certainly they came in the cattle brought from Coepang in Timor in 1824 or 1840.

6. The Buffalo cannot be implicated so far.

7. The original parasite and its original host are probably to be sought for in the Indo-Malayan gaur or wild ox (*Bos* (*Bibos*) *gaurus*), from which also *O. gutturosa* may be derived indirectly through *O. indica*.

8. No evidence is forthcoming as to the life-history, from any source.

In conclusion, I wish to express my thanks to Professor Baldwin Spencer and to Professor H. A. Woodruff for permission to use their laboratories in this University for the purpose of this research, and to them and to Dr. T. S. Hall and Mr. H. R. Seddon, for their kind interest and ready help.

ADDENDUM 1.

Since the foregoing report was presented, I have received a further supply of nodules (a) from cattle (*Bos indicus*) from Southern Siam, sent by Mr. S. L. Symonds from Serembam, F.M.S., and (b) from 3 Indian buffaloes (*Bos bubalis*) from Mr. C. W. Wilson, from Aligarh, United Provinces, India.

(a) These are typical nodules of *O. gibsoni*, with the characteristic dense fibrous capsule much thicker than in *O. indica*. In one nodule no male could be found, although the female contained fully developed eggs and larvae. Caseation was considerably advanced in parts of this nodule, and neither the head nor the tail of the female could be found. In the second nodule there was much

1 And see Addendum 1, *re* its presence in buffalo in India.

extravasation of blood into the worm-tunnels, and the anterior end of the female and most of the male were caseated. In the third nodule there was also much extravasation into the worm-tunnels, and caseation of nodule and worms, but the heads of both male and female, and the tail of the male, were obtained, and served but to confirm the observations made in the body of this report on nodules from Siam, provided by Mr. T. A. Ford, these worms being certainly *O. gibsoni*.

One or two peculiarities in this specimen are specially noteworthy, the remarkable distance (1.24 mm.) of the opening of the vulva from the anterior end, even for *O. gibsoni*, in which it is often so much greater than in *O. indica* (cf. Leiper's description of 1.23 mm.). Also in the male, are found a remarkably short, thin oesophagus (length .314 mm., and diameter .0094 mm.), and a very short "long" spicule (.138 mm.), which are quite unique even for *O. gibsoni*. These features, with the abnormally thin head and body of the male, emphasise the statement made in connection with the previous material of *O. gibsoni* from Siam, that where any special variations from the average measurements of *O. gibsoni* exist therein, those variations are in an opposite direction to those measurements which are characteristic of *O. indica*. A similar statement is true here of the anal papillae, which are as follow :-

R., preanal 0, adanal 2, postanal 1, caudal 2;
L., preanal 0, adanal 2, postanal 1, caudal 2,

making a total of five on each side—again a smaller number than is usually found in *O. gibsoni*.

(b) The nodules from the buffalo differ somewhat in external appearance from those found in cattle, the capsule of free nodules being at times much thicker than in *Bos indicus*, and the fibrous tissue much less compacted in the outer part of the capsule than in either *Bos taurus* or *Bos indicus*, though at the same time it is very tough and resistant to cutting or tearing. At other times, a continuous capsule wall is absent, only a trifling amount of fibrous tissue being present, and then forming long independent strands. A quantity of muscular tissue, more or less degenerated, surrounds the nodule in place of the ordinary capsule. Very frequently the nodule is closely united with the skin (see Fig. 12). There may be then also no true capsule wall, the nodule (=worm-area only) lying in the subcutaneous muscular tissue. There is present a very small amount of white fibrous tissue forming long bundles emerging irregularly from the worm-area and mingling with the fibrous tissue of the subdermal layers. The trabeculae forming the walls of the

worm-tunnels have a considerable quantity of fibrous tissue. These nodules are inseparable except by cutting from the skin, as contrasted with the smooth surfaced compact capsule of *O. gibsoni* in either *Bos taurus* or *Bos indicus*, or of *O. indica* in *Bos indicus*. This firm attachment to the skin in the buffalo is attributed by Mr. Wilson "to the density of the subcutal structures in that animal." He also states that "the 'nests' show more tendency to calcify quickly in the buffalo than in cattle," but that he has "failed to notice any variation in colour" such as was mentioned by one observer. The hairlessness of the skin over the nodule, noted by the same observer, is apparent slightly, in one of the specimens, but I cannot detect any thinning of the skin in that position. These nodules were taken from the vicinity of the sternum in three buffaloes, 8, 11 and 12 years old respectively, considerable caseation being present in several, e.g., in II., in which the head and tail of the female were not found, and III., in which the head of the male is missing. (See Tables 9, 10 and 11.) Nodule II. had two males with the one female, while one male only was present in each of the others. Commencing caseation also accounts for some uncertainty in regard to the anal papillae in the males II. 1 and II. 2, while the tail of the male III. was much distorted, the long spicule having torn through the postanal tissues.

Reference to the tables (9, 10, and 11) herewith added, and their comparison with those previously given will be found to establish the conclusion that these nodules in *Bos bubalis* in India are caused by the same species of worm as causes those in *Bos indicus* in India, viz., *O. indica*. In the male the thicker anterior end, the longer thicker oesophagus, the slightly more anterior cloacal opening, the thick and longer large spicule characteristic of *O. indica* are all present, while in I., and as far as can be seen in II. 1 and II. 2, the anal papillae are such as are found in that species. In the female, the thinner anterior end characteristic of *O. indica* is found, with a fairly long oesophagus, and also a more posteriorly placed anus, but the other features are not so characteristic, though still such as are found in other specimens of *O. indica*.

It will be seen that this further material entirely confirms the conclusions arrived at in the body of this Report (1) that the nodule worm of India is a new species different from that of Australia, (2) that the nodule worm of Siam or Malaya is similar to that of Australia, (3) that the Indian buffalo has not been the carrier of this parasite into Australia, and (4) that Malaya or the Malay Archipelago has been the source of the infection of Australian cattle.

ADDENDUM 2.

Since the foregoing has been printed, I have received from Dr. L. de Blieck, Director of the Government Veterinary School at Buitenzorg, Java, a statement by Dr. Smit of the results of the enquiries made by the Dutch authorities at my request, into the occurrence of worm nodules in Netherlands India.

The following is a translation of this report :—" I have often observed the ' worm-nodules ' caused by *Onchocerca gibsoni* at the abattoir at Buitenzorg. They have been seen in native as well as in cross-bred cattle (i.e., of native with European, Australian, and Bengal (Zebu) cattle). They have been mostly found in cattle originating from Gombong, and Poerworedjo, principally in Javanese cattle. Several times, however, they have been seen in animals originating from the Buitenzorg district and Bantam, also in cross-bred Australian and in the few Australian cattle killed at Buitenzorg.

" At Batavia, Mr. Jenne found them to occur in nearly every animal killed (these being imported Australian).

" In native cattle they were only found in the breast muscles; in Australian cattle at Batavia, however, they were found also in the abdominal muscles in front of the stifle.

" Out of about 4000 karbouws inspected, two were found to have one worm-nodule each—in both cases in the breast muscles—which macroscopically differed in no way from the worm-nodules in cattle. It is seen from this, that they only very rarely occur in karbouws. Mr. Sohns was able to inform me that they have been repeatedly found by him in the residencies of Rembong and Kediri, in the breast muscles of native cattle. He also found them in the karbouws, but only very seldom.

" Finally, it may be stated that Mr. de Does a short time ago personally intimated to me, that he had also seen them in cattle at Poeloe Laoet, an island at the S.E. point of Borneo.

" Briefly stated, it may therefore be accepted that worm-nodules caused by *Onchocerca gibsoni* occur over the whole of Java in native as well as cross-bred native cattle, and in karbouws. Further, that the said disease has also been found on other islands (Poeloe Laoet) of the Archipelago."

The term, native cattle, employed in Dr. Smit's report, cannot obviously refer to the original wild ox of Java, the Bantin (*Bos* (*Bibos*) *banteng*). It is, however, undoubtedly applied to animals of the *Bos indicus* type bred in Java, and possibly the direct

descendants—either pure bred or hybrid—of the Bantin, which, as pointed out above (see p. 3), is regarded as being, at least, closely allied to the ancestor of the Zebu.

Material has been sent to me from Java, but is not yet to hand. The results of its examination, and the relationship of the nodule worms in the Javanese *Bos indicus*, in the hybrid *Bos indicus* (Javanese X Bengalese), and in the Javanese Karbouw, will form the subject of a later report by myself.

In reference to the Indian cattle, *Bos indicus*, imported into the United States of America from infected areas in India (see p. 14), I am informed by Dr. B. H. Ransom that so far as the officers of the Bureau of Animal Industry have been able to make any observations, worm-nodules have not been discovered.

26th May, 1915.

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Fig. 7. Tail of male worm (i), in nodule D, of *O. indica*, n. sp., from *Bos indicus*, India, (a) anus.

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Fig. 9. Tails of six male specimens of *O. indica*, n. sp., from *Bos indicus*, India, drawn to scale from ventral surface, to show anal papillae, (a) anus.

Fig. 10. Tails of six male specimens of *O. gibsoni*, from *Bos indicus*, from Siam and Malaya, drawn to scale to show anal papillae, (a) anus.

Fig. 11. Tails of three male specimens of *O. indica*, from *Bos bubalis*, India.

Fig. 12. Showing relationship of superficial nodule in *Bos bubalis* to skin and subdermal tissues—microphotograph.

All other figures than photographs outlined by camera lucida.

TABLE 1.—MALES FROM NODULES FROM INDIAN CATTLE.

Males.	Bi.	Bii.	C.	Di.	Dii.	E.	Range.	Average.
Length of male	cm. 5·3	cm. 9·3	cm. ? 5·5	cm. 6·2	cm. 4·5	cm. 3·38	cm. 3·38—9·3	cm. 5 69
Diameter ·15 mm. from anterior end	mm. ·079	mm. ·069	mm. ·075	mm. ·069	mm. ·075	mm. ·062	mm. ·062 — ·079	mm. ·071
Diameter at middle	·193	·204	·220	·207	·175–·183	·207	·175 — ·220	·198
,, ·5 mm. from anterior end	·100	·096	·103	·103	·103	·082	·082 — ·103	·098
,, level of cloacal opening	·050	·062	·062	·051	·054	·042	·042 — ·062	·053
Excretory pore from anterior end	?	?	?	? ·219	? ·282	?	?·219 — ·282	? ·250
Nerve ring from anterior end	·188	·172	·188	·172	·188	·188	·172 — ·188	·182
"Cardia" from anterior end	1·08	"Cardia" ill-defined.	1·16	1·00	·877	"Cardia" not seen.	·877 —1·16	1·03
,, length	·069		·062	·062	·062		·062 — ·069	·064
,, diameter	·060		·053	·053	·047		·047 — ·060	·053
Œsophagus, length	1·15	1·08	1·22	1·067	·942	·847+	·847+ —1·22	1·051+
,, diameter	·033	·037	·039	·036	·039	·031	·031 — ·039	·036
Cloacal opening from posterior end	·062	·086	·083	·072	·062	·062	·062 — ·086	·070
Spicules—length (long)	·266	·274	·266	·262	·266	·207	·207 — ·274	·257
Spicules—length (short)	·083	·094	·091	Absent.	·086	·080	·080 — ·094	·087
,, diameter (long)	·012	·0117	·013	·011	·0124	·0094	·0094 — ·0124	·0116
,, diameter (short)	·012 (flat)	·007	·0078	Absent	·0062	·0062	·0062 — ·012	·0078
Cuticle thickness	..	..	..	..	..	..	·003 — ·004	..
Transverse ridges apart	..	..	..	..	..	..	·005 — ·006	..
Anal papillæ (see Table 2 for details)	R. L. 7. 9.	R. L. 8. 9.	R. L. 9. 8.	R. L. 8. 9.	R. L. 9. 9.	R. L. 8. 9.	R. L. 7–9. 8–9.	..

TABLE 2.—ANAL PAPILLÆ OF MALES FROM NODULES FROM INDIAN CATTLE.

—	Bi.		Bii.		C.		Di.		Dii.		E.		Range.	
Side of Body.	R.	L.	R.	L.	R.	L.	R.	L.	R.	L.	R.	L.	R.	L.
Preanal	?	1	1	1	1	1	1	1	1	1	1	1	1	1
Par- or ad-anal ..	2+2	1+3	2+2	3	3+1	3+1	2+1	3+1	3+1	2+2	3	2+2	3–4	3–4
Postanal	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Precaudal ..	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Caudal	1	2	1	2	2	1	2	2	2	2	1+1	2	1–2	1–2
Totals ..	7.	9.	8.	8.	9.	8.	8.	9.	9.	9.	8.	9.	7–9.	8–9.

[In this table, the figures succeeding the sign + indicate the number of papillæ smaller than those preceding the sign.]

TABLE 3.—FEMALES FROM NODULES FROM INDIAN CATTLE.

Females.	A.	B.	C.	D.	E.	Range.	Average.
Length of female	..	..	cm. 100	..	..	cm. 100+	..
	mm.	mm.	mm.	mm.	mm.	mm.	mm.
Diameter ·15 mm. from anterior end ..	·096—·117	·082	·075	·093	·069	·069 — ·117	·089
,, at middle	·38	·47	·527	·483	·63	·38 — ·63	·47
,, just in front of vulva ..	·103	·124	·096	·114	·096	·096 — ·124	·106
,, level of anus	..	(Not seen)	·189	·172	·125	·125 — ·189	·162
Excretory pore from anterior end	..	(Not seen)	..	..	..	(Not seen)	..
Nerve ring from anterior end	..	·188	·188	·188	?	·188	·188
"Cardia" from anterior end	..	1·03	1·05	1·13	?	1·03 —1·13	1·07
,, length	..	(Ill-defined)	Very slight	·062	?	·062	·062
,, diameter	..	·055	Very slight	·045	?	·045 — ·055	·050
Œsophagus, length	..	1·17	1·1	1·20	1·44	1·1 —1·44	1·23
,, diameter	..	·031	·031	·034	·031	·031 — ·034	·032
Vulva from anterior end	·63	·62	·60	·55	·75	·55 — ·75	·63
Anus from posterior end	..	(Not seen)	·232	·125	·204	·125 — ·232	·187
Cuticle thickness (middle)	..	..	..	..	..	·0209— ·024	..
Spiral ridges (middle)	..	..	..	..	..	·138 (apart)	..
Segmented ovum	..	..	..	..	..	·026 × ·017	..
Eggs containing developed larva	·0314× ·0196	·0251× ·0172	·0282× ·0235	·0329× ·0251	·0314× ·0204	·0251—·0329 × ·0172—·0251	·0298 × ·0211
Larva just escaped from egg	..	·12× ·0021	·182× ·0023	·126× ·0021	·196× ·0024	·12 —·196 × ·0021— ·0024	·156 × ·0022

TABLE 4.

Range of Measurements in Species of Onchocerca found in the Subcutaneous and Intermuscular Connective Tissues of Cattle.

Males.	Onchocerca gibsoni.					
	Cleland and Johnston.	Breinl.	Leiper.	Gilruth and Sweet.	Average of own Measurements.	Average of all observers' Measurements.
Length of male	..	em. 3·316—5·5 at ·175 mm.	em. 5	em. 3·8—5·3	em. 4·6	em. 4·297
	mm.	mm.	mm.	mm.	mm.	mm.
Diameter ·15 mm. from anterior end	..	·042— ·066	..	·052 — ·062	·059	·054
,, at middle	·15 at ·65	·143— ·196	·15	·141 — ·151	·145	·167
,, ·5 mm. from anterior end	·085	..	..	·069 — ·082	·078	..
,, at level of cloacal opening	..	·035— ·056	·04	·042 — ·051	·045	·044
Cervical dilatation	..	..	..	..	..	..
Excretory pore from anterior end	..	·238— ·280	..	·251	·251	·256
Nerve ring from anterior end	·18	·140— ·175	·2	·172 — ·188	·180	·164
"Cardia" from anterior end	..	..	..	..	..	..
,, length	..	..	..	..	..	..
,, diameter	..	[? ·075]	[? ·05]	..	..	..
Œsophagus length	..	·484—1·074	·8	·65 — ·72	·68	·742
,, diameter	..	·015— ·075	·02 — ·05	·0155	·0155	·020
Cloacal opening from posterior end	·072*	·052— ·087	·07	·048 — ·062	·054	·066
Spicules—length (long)	·14 and ·197	·143— ·220	·18	·148 — ·155	·153	·177
Spicules—length (short)	·047 and ·082	·063— ·085	·08	·078 — ·094	·083	·075
,, diameter (long)	..	·007— ·014	·005	·0078— ·010	·0089	·0083
,, diameter (short)	..	·006— ·008	·002— ·005	·0061— ·0078	·007	·0068
	..	..	..	·0033— ·0047	..	..
Cuticle thickness	..	..	..	·0045— ·0060	..	..
Transverse ridges apart	100 to ·5 = ·005	..	·045 [? G.S.]	..	..	..
Oral papillæ and lips	..	No papillæ, 3 lips	..	3 lips and 3 papillæ	..	..
Anal papillæ — Side of body	R. L.	R. L.	R. L.	R. L.	..	..
Preanal	0 0	1–2 1–2	0 0	1 1–2	..	..
Par- or adanal	4 4	3 3	4 4	3 3	..	..
Postanal	2 2	3 3	0 0	1 1	..	..
Caudal	.. ..	.. ..	2 2	2 2	..	..

* ·65 mm. in same paper is obviously an error in transcription,

TABLE 4—*continued.*

Males.	Range of Measurements in Species of Onchocerca found in the Subcutaneous and Intermuscular Connective Tissues of Cattle.				Other Species of Onchocerca.				
	O. indica.		O. gutturosa.	O. bovis.	O. fasciata.	O. volvulus.	O. reticulata.	O. cervicalis.	O. armillata.
	Range.	Average.							
	cm.	cm.	cm.	cm.		cm.	cm.		cm.
Length of male	3·38—9·3	5·69	2·83—3·38	4—5·5	unknown	2·0—4·5	27	(?)	8·87
	mm.	mm.	mm.	mm.		mm.	mm.	mm.	mm.
Diameter ·15 mm. from anterior end	·062 — ·079	·071	..	..	..	..	..	..	..
,, at middle ..	·175 — ·220	·198	·091 — ·105 at ·45 mm.	·085— ·095	..	·150— ·200	·150	·175— ·20	·190
,, ·5 mm. from anterior end	·082 — ·103	·098	·35 [?·035 G.S.] at ·45 mm. post	..	..	..	..	..	..
,, at level of cloacal opening	·042 — ·062	·053	·058	..	..	..	..	..	..
Cervical dilatation ..	..	..	·08 at ·35 fr. ant.	..	..	..	..	..	..
Excretory pore from anterior end	·219 ? — ·282?	?·250	..	..	..	..	..	..	..
Nerve ring from anterior end	·172 — ·188	·182	..	..	..	..	..	..	..
" Cardia " from anterior end	·877 —1·16	1·03	..	..	..	..	..	..	..
,, length	·062 — ·069	·064	..	..	..	..	..	..	..
,, diameter ..	·047 — ·060	·053	..	..	..	..	..	..	..
Œsophagus length ..	·847+?—1·22	1·051+	·95	·75 — ·80	..	..	..	2·3— 2·4	..
,, diameter ..	·031 — ·039	·036	very thick at cervical dilatation	..	..	..	..	..	..
Cloacal opening from posterior end	·062 — ·086	·07	..	..	..	..	..	..	..
	sometimes bifid	point	bifid point	pointed					
Spicules—length { long ..	·207 — ·274	·257	·225 — ·295	·180— ·210	..	·166— ·230	·200— ·260	·330— ·350	·195
{ short	·082 — ·094	·087	·075 — ·088	·065— ·075	..	·080— ·082	·100— ·120	·100— ·120	·126
,, diameter { long ..	·0094 — ·0124	·0116	..	..	..	..	..	..	..
{ short	·0062 — ·012	·0078	..	..	..	..	..	..	..
Cuticle thickness	·003 — ·004	·0035	·004	..	..	..	..	..	..
Transverse ridges apart ..	·005 — ·006	·0055	{ only striæ (·0015— ·0018	·005— ·006	..	..	..	..	..
Oral papillæ and lips ..	3 lips and 3 papillæ	..	2+2 papillæ	..	..	..	..	..	..
	R. L.	..	R. L.	R. L.	..	R. L.	R. L.	R. L.	..
Anal papillæ { Side of body ..		..			..				..
{ Preanal ..	1 1	..	0 0	0 0	..	0 0	2 3	1 1	?
{ Par- or adanal	3–4 3–4	..	4 3–4	4 4	..	4 4	4 4	4 4	..
{ Postanal ..	1 1	..	2 2	1 1	..	0 1	0 2	2 2	?
{ Caudal ..	1+1-2 1+1-2	..	1 1	2 2	..	2 2	1 1	2 2	..

TABLE 5.

Range of Measurements in Species of Onchocerca found in the Subcutaneous and Intermuscular Connective Tissue of Cattle.

Females.	Onchocerca gibsoni.					
	Cleland and Johnston.	Breinl.	Leiper	Gilruth and Sweet.	Average of own Measurements.	Average of all observers' Measurements.
	cm.	cm.		cm.	cm.	cm.
Length of Female	97	77—133	..	52·6—140·3	94·3	73
	mm.	mm.	mm.	mm.	mm.	mm.
Diameter ·15 mm. from anterior end	..	·049 — ·143 · at ·18 mm.	·1 ? here	·078 — ·123	·101	·104
,, at middle	·43 — ·38	·4— ·6	·4— ·5	·37 — ·45	·40	·43
,, just in front of vulva	·16	..	..	·106 — ·207	·138	..
,, at level of anus	..	·175 — ·245	..	·207	·207	·188
Cervical dilatation—diameter	..	..	..	..	..	..
Excretory pore from anterior end	..	·175 — ·294	..	·358 — ·379	·368	·301
Nerve ring from anterior end	..	·102 — ·182	..	·142 — ·188	·170	·171
" Cardia " from anterior end	..	..	..	·41 — ·86	·66	..
,, length	..	..	..	·031 — ·062	·039	..
,, diameter	..	..	..	·031 — ·040	·033	..
Œsophagus, length	..	·615 —1·424	1	·52 — ·92	·71	·758
,, diameter	..	·0175— ·052	·03	·02 — ·021	·0206	·027
Vulva from anterior end	·8	·332 —1·176	1·23	·46 —1·138	·689	·721
Anus from posterior end	..	·175 — ·402	..	·175 — ·207	·191	·250
Cuticle thickness	..	..	..	·0078— ·0109	·0093	..
Spiral ridges apart	6-8 in ·5 mm.	..	..	..	..	..
Oral papillæ and lips	..	3 lips and 3 papillæ	..	3 lips, each with 1 papilla	..	..
Caudal papillæ	..	3	..	..	..	..
Ovum just segmented	..	..	..	·026 × ·017	..	..
Egg containing developed larva	·03 × ·045	..	·03 × ·04	·043 — ·045 × ·03 — ·039	..	..
Larva just escaped from egg	·22 — ·27 × ·0033— ·004	..	·22 × ·003	·23 — ·35 × 0031— ·0041	..	..

TABLE 5—*continued.*

Females.	Range of Measurements in Species of Onchocerca found in the Subcutaneous and Intermuscular Connective Tissue of Cattle.				Other Species of Onchocerca.				
	O. indica.		O. gutturosa.	O. bovis.	O. fasciata.	O. volvulus.	O. reticulata.	O. cervicalis.	O. armillata.
	Range.	Average.							
Length of Female	cm. 100 mm.	.. mm.	cm. 55+ mm.	cm. 26+ mm.	? mm.	cm. 60—70+ mm.	cm. 75+ mm.	? mm.	? mm.
Diameter ·15 mm. from anterior end	·069 — ·117	·089	·081 ? here	..	..	..	..	..	..
,, at middle ..	·38 — ·63	·47	·3	·26 — ·29	·40— ·475	·30— ·35	·30	·40	·40 — ·45
,, just in front of vulva	·096 — ·124	·106	..	..	..	..	..	..	..
,, at level of anus ..	·125 — ·189	·162	..	..	..	..	..	..	..
Cervical dilatation, diameter	..	..	·09 — ·1	..	..	..	..	..	..
Excretory pore from anterior end	..	..	..	..	..	..	..	..	..
Nerve ring from anterior end	·188	·188	..	..	..	..	..	..	..
"Cardia" from anterior end	1·03 —1·13	1·07	..	..	..	..	..	..	..
,, length	·062	·062	..	..	..	..	..	..	..
,, diameter ..	·045 — ·055	·050	..	..	..	..	..	..	..
(Esophagus, length ..	1·1 —1·44	1·23	1·15	·82 — ·85	..	..	3·5	2·4	..
,, diameter ..	·031 — ·034	·032	..	..	..	..	..	..	..
Vulva from anterior end ..	·55 — ·75	·63	·55	63 — ·65	..	·55— ·76	·40— ·58	·375— ·410	1·150—1·300
Anus from posterior end ..	·125 — ·232	·187	·2	..	..	..	..	..	..
Cuticle thickness	·0209— ·024	..	·035— ·047	..	..	..	..	..	..
Spiral ridges apart ..	·138	..	..	..	..	..	..	..	..
Oral papillæ and lips ..	3 lips each with 1 papilla	..	2 + 2 papillæ	..	..	..	..	..	..
Caudal papillæ	..	..	..	..	..	..	..	..	..
Ovum just segmented ..	·023 × ·017	..	..	..	..	..	..	..	..
Egg containing developed larva	·0251— ·0329 × ·0172— ·0251	·0298 × ·0211	·035— ·045 × ·028— ·035	·048— ·053 × ·034— ·036	..	..	..	..	..
Larva just escaped from egg	·12 — ·196 ×0021 · — ·0024	·156 × ·0022	·170— ·195 × ·004	·230— ·265 × ·0055	..	..	..	..	..

TABLE 6.—MALES FROM NODULES FROM SIAMESE (1 AND 2) AND MALAYAN CATTLE (3 AND 4).

Males.	1	2	3	4i.	4ii.	4iii.	Range.	Average.
Length of male	cm. 5	cm. 4·3	cm. 4·5	cm. 3·5+	cm. 4·8	cm. 4·3	cm. 3·5 +–5	cm. 4·4+
Diameter ·15 mm. from anterior end	mm. ·062	mm. ·034	mm. ·055	mm. ·044	mm. ·055	mm. ·055	mm. ·034 — ·062	mm. ·051
,, at middle	·148	·180	·168	·125	·125	·157	·125 — ·180	·150
,, ·5 mm. from anterior end	·069	·055	·079	·062	·075	·075	·055 — ·079	·069
,, level of cloacal opening	·043	·049	·039	·0314	·039	·039	·031 — ·043	·038
Excretory pore from anterior end ..	..	..	..	..	..	..	..	..
Nerve ring from anterior end ..	·188	·172	·188 ?	·157	..	?	·157 — ·188	176
" Cardia " from anterior end ..	..	..	..	..	..	..	..	..
,, length	..	..	..	..	..	..	..	..
,, diameter	..	..	..	..	..	..	..	..
Œsophagus, length	·94	1·1	·828	·828	·690+	·82	·690+–1·1	·867+
,, diameter	·023–·028	·015	·018	·019	·018	·015	·015 — ·028	·019
Cloacal opening from posterior end ..	·062	·062	·062	·062	·067	·070	·062 — ·070	·064
Spicules—length .. .. long	·152	·188	·190	·172	·172	·188	·152 — ·190	·177
Spicules—length .. .. short	·078	·062	·070	·065	·070	·078	·062 — ·078	·070
,, diameter .. long	·009	·007	·011	·007	·008	·007	·007 — ·011	·008
,, diameter .. short	·005	·006	·003	·003	·004	·004	·003 — ·006	·004
Cuticle thickness	·0039	·0031	·0055	·006	·006	·004	·003 — ·006	·0047
Transverse ridges apart	·005	·005	·005	·005	·005	·005	·005	·005
Anal papillæ (see Table 7 for details)	R. L. 7. ?.	R. L. 6. ?.	R. L. 5+1 ?. 7.	R. L. 5+?. 7.	R. L. 4+?. 7.	R. L. 6. 5+1 ?.	R. L. 4+?–7. 7–8.	.. ..

TABLE 7.—ANAL PAPILLÆ OF MALES FROM SIAMESE (1 AND 2) AND MALAYAN CATTLE (3 AND 4).

——	1	2	3	4i.	4ii.	4iii.	Range.
Side of Body.	R. L.	R. L.	R. L.	R. L.	R. L.	R. L.	R. L.
Preanal	1 ..	— ..	— 1	? 1	— 1	— —	1 1
Par- or ad-anal ..	3 ..	3 ..	3 2+2	2 3	2 3	3 3	2—3 3—4
Postanal	1 ?	1 ?	1 —	1 1	? 1	1 1	1 1
Precaudal ..	1 ..	1 ..	1 1	1 1	1 1	1 1	1 1
Caudal	1 ..	1 ..	1 ? 1	1 1	1 1	1 1 ?	1 1
Totals ..	7. ?.	6. ?.	5+1 ?. 7.	5+ ?. 7.	4+ ?. 7.	6. 5+1?.	4+?—7.7—8.

[In this table, the figures succeeding the sign + indicate the number of papillæ smaller than those preceding the sign. In 1 L and 2 L, the papillæ were much obscured.]

TABLE 8.—FEMALES FROM NODULES FROM SIAMESE (1 AND 2) AND MALAYAN CATTLE (3 AND 4).

Females.	1	2	3	4iv.	4v.	Range.	Average.
Length of female	The head and tail of this worm could not be found.	(Not taken out whole.)					
		mm.	mm.	mm.	mm.	mm.	mm.
Diameter ·15 mm. from anterior end..		·089	·079	·069	·103	·069 — ·103	·085
,, at middle		·517	·607	·607	·600	·517 — ·607	·583
,, just in front of vulva ..		·124	·124	·103	·131	·103 — ·131	·120
,, level of anus		·207	·147	..	..	·147 — ·207	·177
Excretory pore from anterior end ..		..	..	·282	·282	·282	·282
Nerve ring from anterior end ..		·157	·172	·188	·157	·157 — ·188	·168
"Cardia" from anterior end ..		..	..	..	..	..	..
,, length		..	..	..	..	..	..
,, diameter		..	..	..	..	..	..
Oesophagus, length..		·89	·76+?	·879	·966	·76+ — ·96	·874+
,, diameter		·017	·025	·017	·024	·017 — ·025	·021
Vulva from anterior end		·45	·66	·55	·56	·45 — ·66	·55
Anus from posterior end		·276	·414	..	..	·276 — ·414	·345
Cuticle, thickness		·007	·006	·013	·005	·005 — ·013	·008
Spiral ridges apart		·110	·083	·110	·106	·083 — ·110	·105
Segmented ovum		..	·0314×	·0188	·026×·017	·026 — ·0314 ×·017 — ·0188	·0287×·0179
Eggs containing developed larva ..		..	..	..	..	..	..
Larva just escaped from egg ..		·22×·0047	·23×·005	..	·188×·0039	·188 — ·23× ·0039 — ·005	·209×·0044

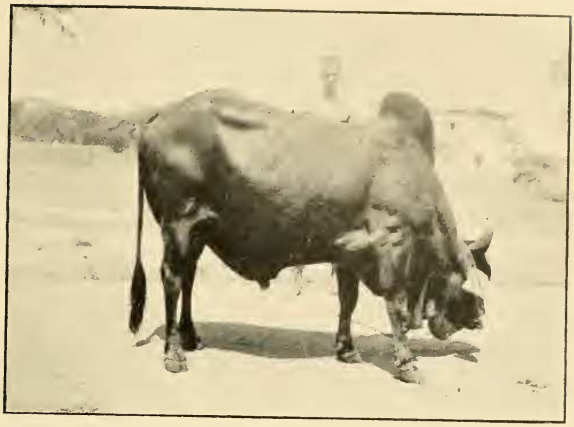

Fig. 1.

Fig. 2.

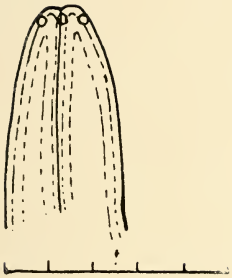

Fig. 5.

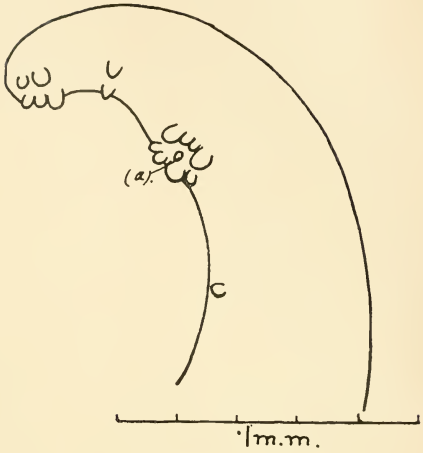

Fig. 6.

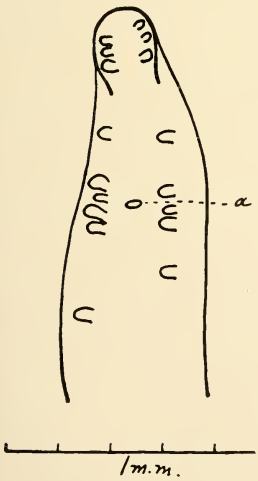

Fig. 7.

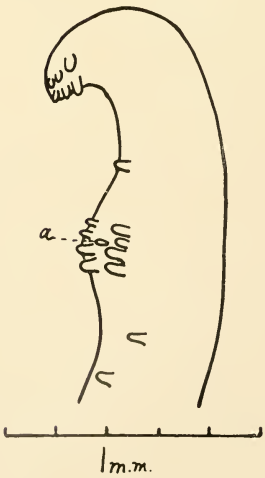

Fig. 8.